Variability of Tropospheric Carbon Dioxide in the Greater Houston Metropolitan Area.

AIRS
AQUA
DISCOVER-AQ

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NASA LEARN Program

The NASA LEARN Project is an innovative program that provides educators with on-site research and training with NASA scientists during the summer and guided research projects that continue on throughout the school year. These educators conduct their own research, with help of a team of NASA scientists, through on-site collaboration and virtual meetings. They share and integrate these projects into the classroom, concluding the process by presenting their projects at a final poster session attended by the NASA Langley Science Directorate. This work was supported by the Long-term Engagement In Authentic Research with NASA (LEARN) project with funding provided through a NASA SMD EPOESS grant.

Background

Carbon dioxide, a naturally-occurring trace gas comprising nearly 0.04% of Earth's atmosphere, has gained considerable attention in recent decades for its ability to store thermal (IR) energy, contributing to the phenomenon called the Greenhouse Effect. This compound, combined with the effects of water vapor, methane, CFCs, and ozone, among others, alter Earth's radiation budget to produce higher global temperatures, local weather extremes, and changes to planetary ecology.

Because carbon dioxide is a very stable molecule (two double-bonded oxygen atoms), it has the ability to absorb energy, particularly infrared (IR) energy at wavelengths that typically escape Earth's atmosphere after first being absorbed by surface objects (12-13 μm, among others). The result is a partial closing of the "window" to Earth's normal radiative cooling, with a subsequent increase of temperature due to the trapped heat energy in the system.

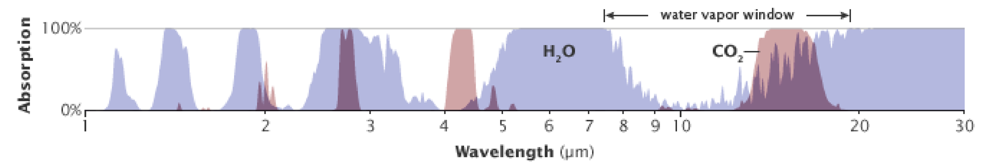


Figure 2: Carbon dioxide absorbs wavelengths of re-radiated energy that typically escapes the atmosphere; with increasing CO_2 levels, more energy is trapped in the system (Illustration courtesy of NASA and Robert Rohde).

Project Focus

The purpose of this investigation is to inform the user regarding the importance of understanding the factors associated with CO_2 in the atmosphere in a particular region. The Houston Metropolitan Area was chosen for the wealth of available data, the need for this type of knowledge in policymaking, and the collaboration afforded by working with research *and* researchers associated with the DISCOVER-AQ program.

Question: Does one localized atmospheric CO_2 reading represent a region or the entirety of Earth's atmosphere?

DISCOVER-AQ Mission

Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ), is a four-year program to improve satellite use for air quality by making low-atmosphere measurements, like ground-based and airborne data collection.

During the 2013 Texas campaign, a variety of atmospheric species were measured, via instruments installed on aircraft (P-3B and B200), radiosondes (2 sites), and ground stations (17).

For this investigation, CO_2 data gathered using the AVOCET instrument, installed on the P-3B aircraft, were utilized. The instrument generates one data point per second.

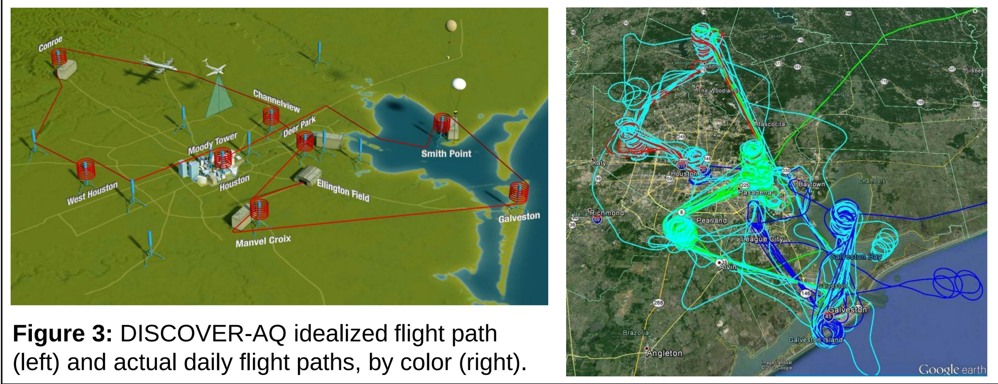


Figure 3: DISCOVER-AQ idealized flight path (left) and actual daily flight paths, by color (right).

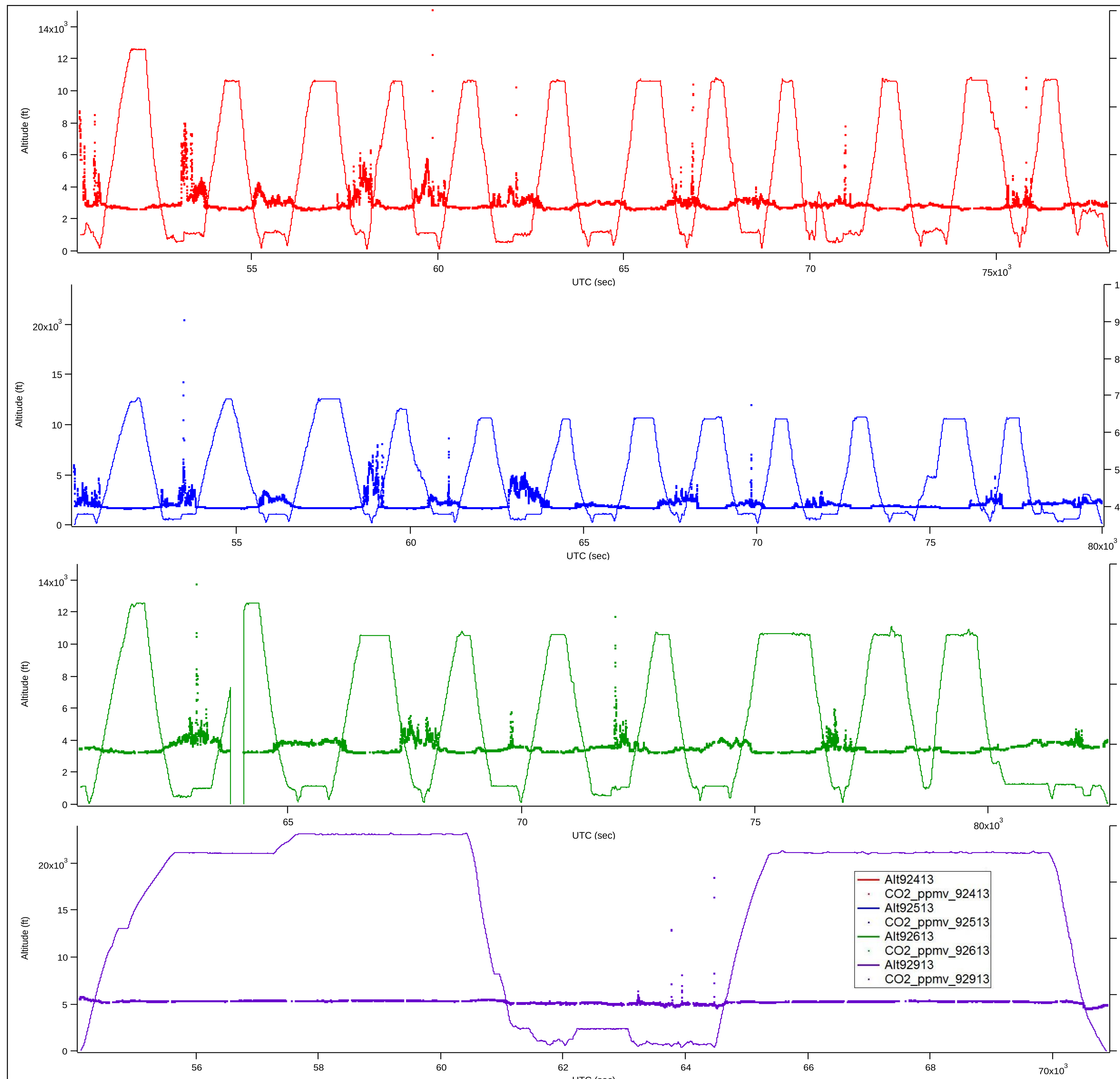
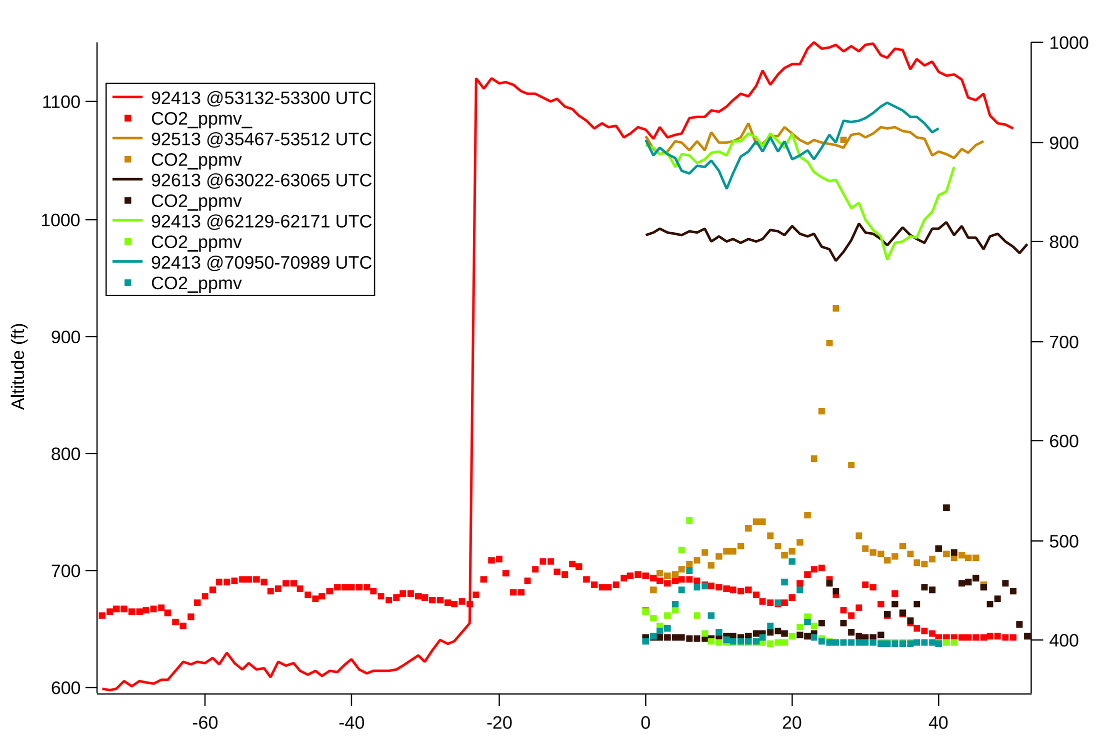


Figure 4: DISCOVER-AQ daily data (altitude and CO_2 readings) from P-3B aircraft missions (Yang). Note the elevated levels of CO_2 in lower altitudes (dots), while most altitude peaks (lines) exhibit more level readings.



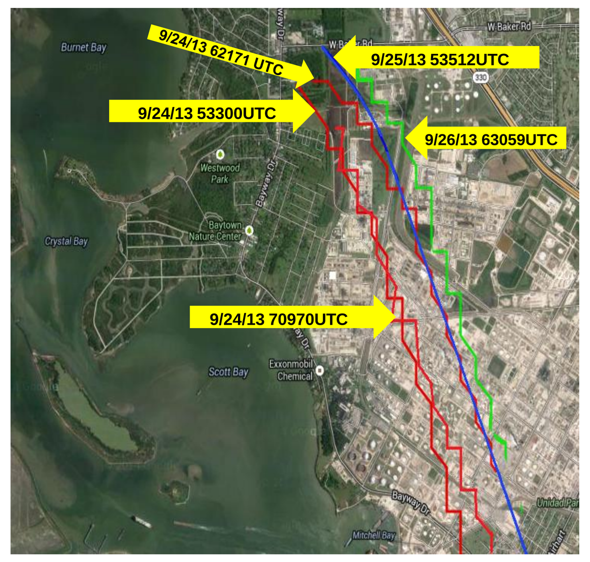


Figure 5/5a: DISCOVER-AQ daily data (left) and approximate location (above; image credit: Google) from ExxonMobil Chemical facility flyovers near Baytown, Texas. The values depicted prior to T=0 represent transit over the Houston Ship Channel.

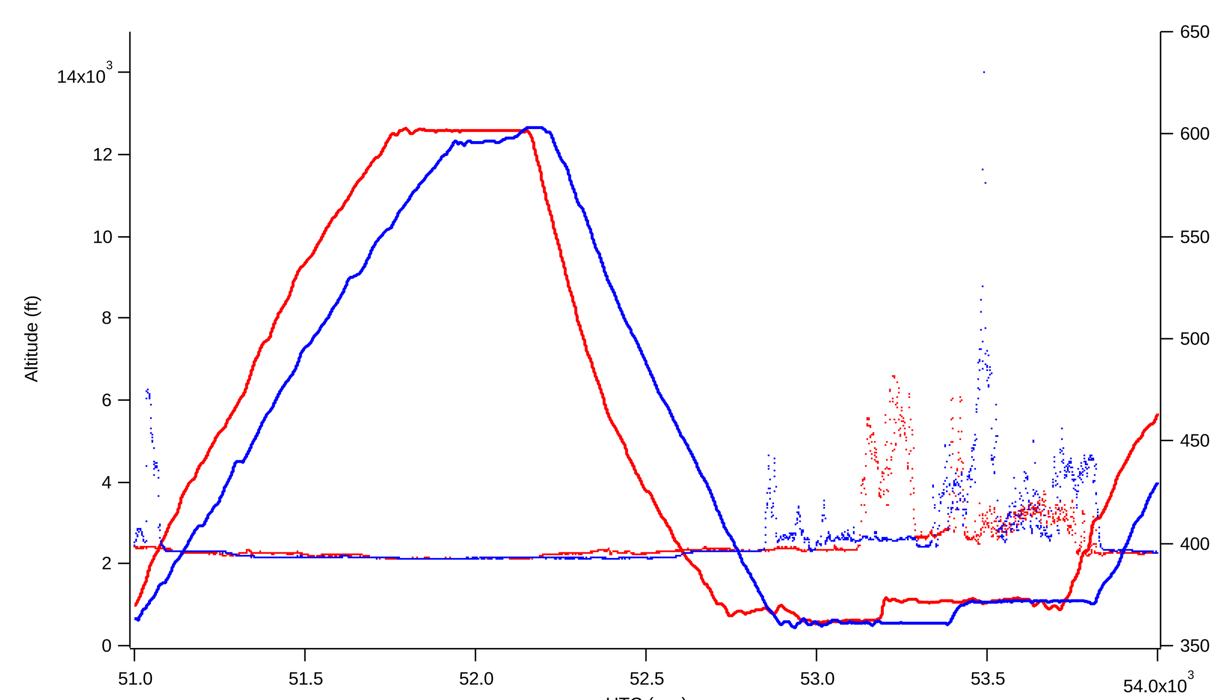


Figure 6: DISCOVER-AQ composite (altitude and CO_2 data) depicting CO_2 variability based on altitude, the most notable examples depicted in the 9/24 (red) and 9/25 (blue).

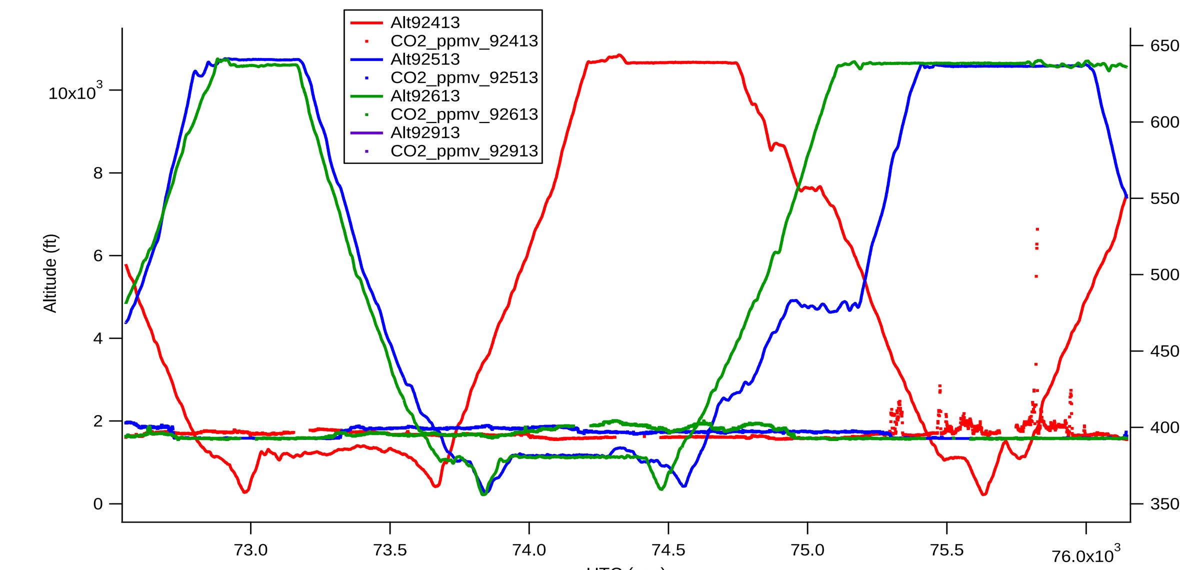
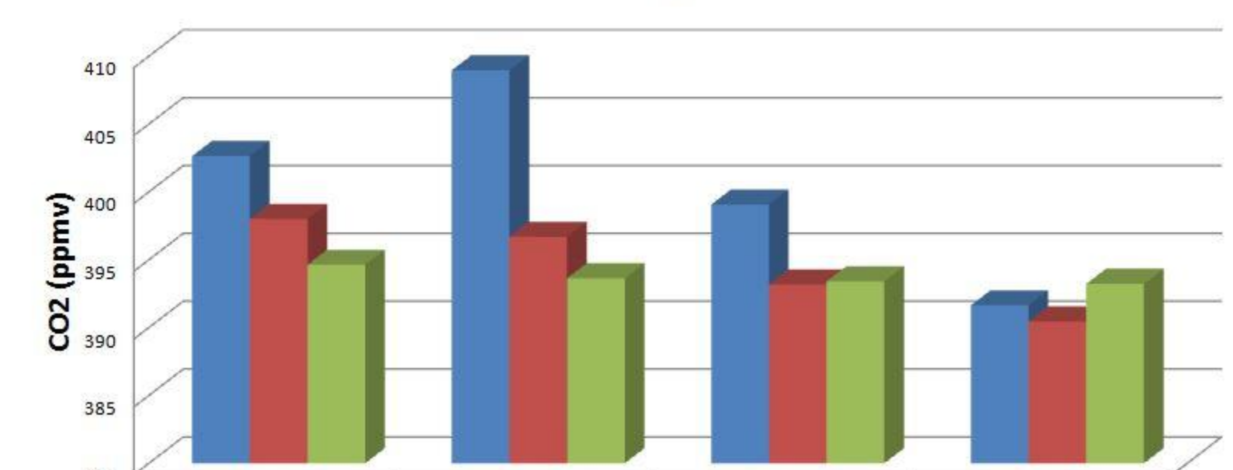


Figure 7: DISCOVER-AQ data composite sample, depicting steady CO_2 readings, contrary to data gathered from other locations during the campaign (Yang).

Average Values for Carbon Dioxide Concentrations, Related to Estimated Boundary Layer; Houston Metropolitan Area



	Sep 24 2013	Sep 25 2013	Sep 26 2013	Sep 29 2013
Below BL	402.64	408.96	399.07	391.64
At BL	398.01	396.69	393.18	390.45
Above BL	394.63	393.64	393.41	393.23

Figure 8: Daily CO_2 data was parsed and means were generated for values at (within 50 feet), below, and above the estimated boundary layer height (BL). METAR data from the closest possible location for which this type of data is available, Houston (Hobby) Airport (KHOU). Note the difference in the 9/29 data; on this day, during this flight, a significant rain event occurred.

AIRS on AQUA

The Atmospheric Infrared Sounder (AIRS), operating on the AQUA satellite provided CO_2 data products from 2002-2012 in the form of monthly averages. These values, with steady annual increases, indicate that 1)overall trends in CO_2 show seasonal increases from one year to the next; 2)the highlighted portion of the graph below (red arrow) that indicates the global annual average remains under the 400 ppmv threshold, and 3)trendline data correlate well to data gathered via other instruments.

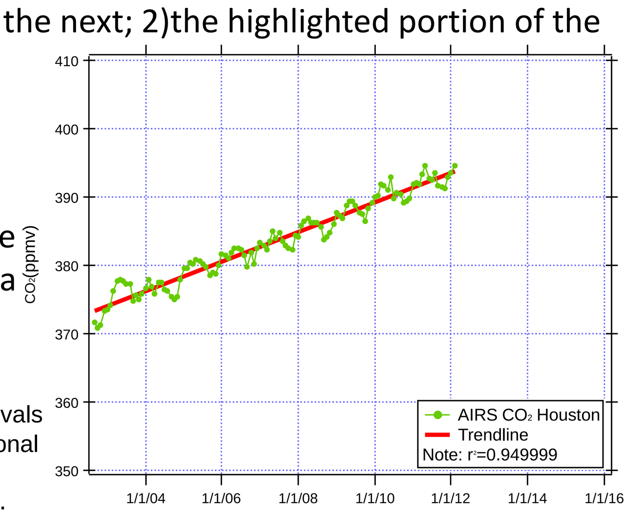


Figure 9: AIRS monthly CO_2 retrievals (2° by 2.5° footprint). Note seasonal "breathing", as well as the arrow displaying current projected value.

GOSAT

The Greenhouse gases Observing Satellite (GOSAT), a joint venture between the Japanese National Institute for Environmental Sciences (NIES), the Ministry of the Environment (MOE), and JAXA, is the first satellite dedicated to greenhouse gas monitoring (CH_4 and CO_2). It scans from low-Earth orbit (about 420 mi), with global coverage every 3 days.

During the DISCOVER-AQ mission, two data points (in ppm) corresponded to the Houston area. Their values, 395.24 and 393.29, adequately reflect the mean obtained above the boundary layer, as well as the AIRS trendline, proving the reliability of the aerial data.

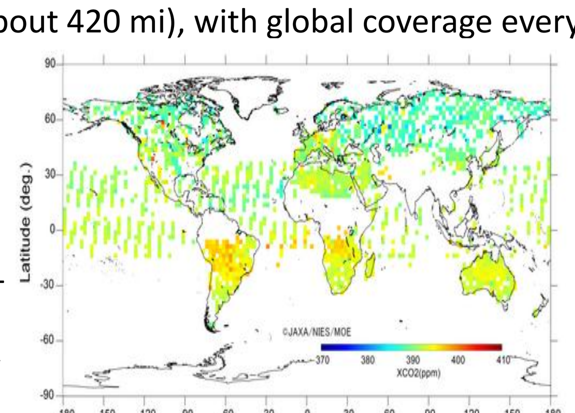


Figure 10: CO_2 column-averaged volume mixing ratios in 2.5 deg by 2.5 deg mesh; August 2013.

Procedure and Results

Data were graphed via Wavemetrics software (Igor) for ease of viewing similarities and differences in the data and for performing basic analyses. Because the datasets were quite large, graphing data was crucial in determining identifying unique occurrences and drawing conclusions, given metadata.

There has been increased media scrutiny of recent reports of CO_2 levels reaching 400 parts per million, on both local and global scales. While conveying this data to the public is vital to continuing the dialogue regarding climate concerns and the environment, understanding the characteristics of the atmosphere and CO_2 require scientists to look at discrete areas, identify qualities that influence emissions, so as to put the best information in the hands of policymakers and the public.

Overall, the qualities observed in the DISCOVER-AQ Texas data lead the user to conclude that factoring in such characteristics as location, human activity, and weather play important roles in understanding CO_2 concentrations in a given area, lending credence to the data .

Student Engagement

On April 23, 2014, in conjunction with the NASA Day of Education program, the 6th grade science students of John Yeates MS (Suffolk, Virginia) were visited by Dr. Lin Chambers, NASA Physical Scientist, to gain insight into Earth's radiation budget and the role of carbon dioxide in the process of this energy exchange. Students (240) left the sessions with valuable information, multimedia for classroom use, as well as some cool free stuff.

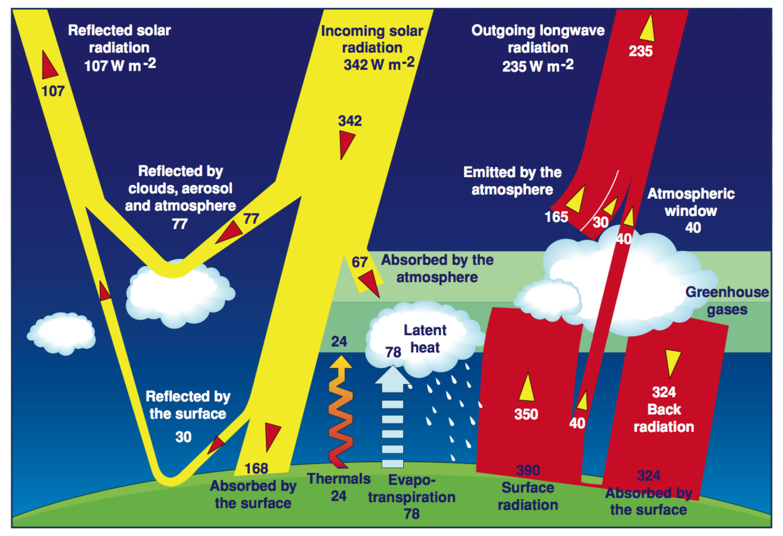


Figure 11: Radiation Balance of the Earth. Note the "back radiation" that occurs when greenhouse gases like carbon dioxide reradiate heat energy in all directions, including back to the Earth's surface(Jeffrey T. Kiehl and Kevin Trenberth).

Radiative Forcing Components

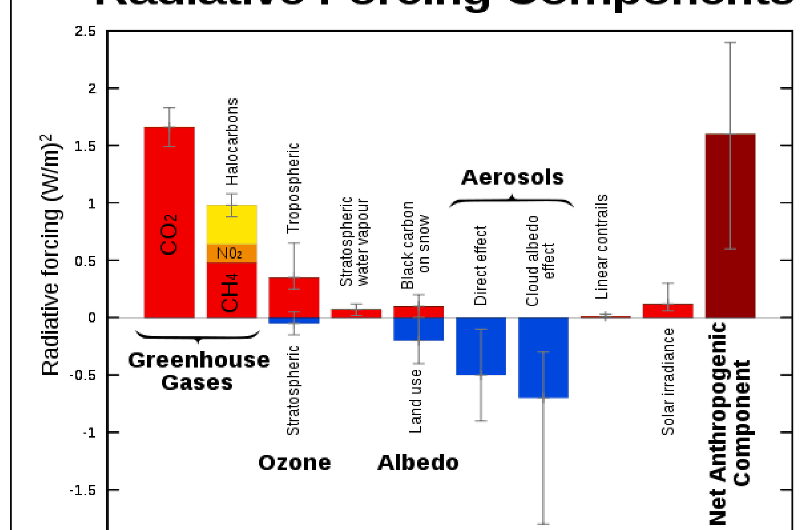


Figure 12: IPCC diagram (2007) detailing significant climate forcing components. Though not depicted, note that CO_2 is present in increasing volume in the atmosphere, thereby trapping more heat in the system, potentially resulting in climate change.

Acknowledgements

•**This work was supported by the Long-term Engagement In Authentic Research with NASA (LEARN) project with funding provided through a NASA SMD EPOESS grant.**

•I'd like to express sincere thanks to Margaret Pippin for her mentoring, Melissa Yang for her data, and Simone Hyater-Adams for technical support in this project. Their patience and help ensured my success.

•Special thanks go to the DISCOVER-AQ team, for allowing me to use their data as the basis for my project.

References

Butler, James H. and Montzka, Stephen A. The NOAA Annual Greenhouse Gas Index (AGGI). In Earth System Research Laboratory; Retrieved June 22, 2014, from www.esrl.noaa.gov/aggi/aggi.html .

Daily Weather Results for KHOU Houston. (n.d.). . Retrieved July 6, 2014, from http://www.wunderground.com/history/airport/KHOU/2013/9/26/DailyHistory.html?req_city=NA&req_state=NA&req_statename=NA .

GOSAT User Interface Gateway (GUIG). *GOSAT User Interface Gateway (GUIG)*. Retrieved July 3, 2014, from http://data.gosat.nies.go.jp/GosatUserInterfaceGateway/guig/GuigPage/open.do .

MYNASADATA Live Access Server. In Mentoring and Inquiry using NASA Data on Atmospheric and Earth Science for Teachers and Amateurs (MYNASADATA). Retrieved July 15, 2012, from http://mynasadata.larc.nasa.gov/ .

Ray, Sharon. (June 4, 2013). The Increase in Carbon Dioxide in Earth's Mid-Troposphere from 2002 to 2013. In NASA AIRS Website. Retrieved June 27, 2013, from http://airs.jpl.nasa.gov/news_archive/2013-co2-400ppm/.

Tans, Pieter. (n.d.). Trends in Atmospheric Carbon Dioxide. In Earth System Research Division: Global Monitoring Division, National Oceanic and Atmospheric Administration. Retrieved June 27, 2013, from http://www.esrl.noaa.gov/gmd/ccgg/trends/.

Wei, J., Savtchenko, A., Vollmer, B., Hearty, T., Albayrak, A., Crisp, D., and Eldering, A.: Advances in CO_2 Observations From AIRS and ACOS, IEEE Geosci. Remote Sens. Lett., 11, 891-895, doi:10.1109/LGRS.2013.2281147, 2014.

Wunch, D., Toon, G. C., Wennberg, P. O., Wofsy, S. C., Stephens, B. B., Fischer, M. L., Uchino, O., Abshire, J. B., Bernath, P., Biraud, S. C., Blavier, J.-F. L., Boone, C., Bowman, K. P., Browell, E. V., Campos, T., Connor, B. J., Daube, B. C., Deutscher, N. M., Diao, M., Elkins, J. W., Gerbig, C., Gottlieb, E., Griffith, D. W. T., Hurst, D. F., Jiménez, R., Keppel-Aleks, G., Kort, E., Macatangay, R., Machida, T., Matsueda, H., Moore, F., Morino, I., Park, S., Robinson, J., Roehl, C. M., Sawa, Y., Sherlock, V., Sweeney, C., Tanaka, T., and Zondlo, M. A.: Calibration of the total carbon column observing network using aircraft profile data, Atmos. Meas. Tech. Discuss., 3, 2603-2632, doi:10.5194/amtd-3-2603-2010, 2010.

Yang, Melissa. Non-dispersive IR Spectrometer Measurements of CO2. NASA DISCOVER-AQ Mission 2013. Retrieved February 15, 2014, from http://www-air.larc.nasa.gov/cgi-bin/ArcView/discover-aq.tx-2013 .